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ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	ji'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kil'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn't i
10^{-3}	milli	m	mil'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	nan'o
10^{-12}	pico	p	pe'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	at'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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XUM

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 8, August 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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CONTENTS

Page

REPORTS

The Determination of Accuracy and Precision Limits for Tritium in Water 405

F. E. Knowles, Jr. and *E. J. Baratta*

DATA

SECTION I. MILK AND FOOD 411

Milk Surveillance, April 1971 411

Food and Diet Surveillance 420

SECTION II. WATER 421

CONTENTS—continued

	Page
SECTION III. AIR AND DEPOSITION	422
Radioactivity in Airborne Particulates and Precipitation	422
1. Radiation Alert Network, April 1971	423
2. Canadian Air and Precipitation Monitoring Program, April 1971	425
3. Pan American Air Sampling Program, April 1971, *PAHO* and *EPA*	426
SECTION IV. OTHER DATA	427
Environmental Levels of Radioactivity at Atomic Energy Commission Installations	427
1. Oak Ridge Area, July–December 1969	427
2. Savannah River Plant, July–December 1970	431
Reported Nuclear Detonations, July 1971	439
Synopsis	iii
Guide for Authors	Inside back cover

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ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Reports

The Determination of Accuracy and Precision Limits for Tritium in Water

Forrest E. Knowles, Jr. and *Edmond J. Baratta*[1]

This paper describes the procedure for establishing a standard deviation (σ) value for analysis of tritium in water and discusses the results of a technical experiment to test the validity of this value. Since many State, Federal and local laboratories are analyzing this radionuclide on a routine basis, a procedure of quality control to assist in producing comparable and accurate data is necessary. As more nuclear power reactors and nuclear fuel reprocessing plants become operative, tritium will be introduced into the environment in greater quantities. Therefore, other agencies are preparing for tritium analysis capability and will be depending upon this quality control program to assess equipment and sample preparation capabilities.

A standard deviation of 10 percent for single determinations for values equal or to greater than 5 nanocuries per liter was established by assessing data from a tritium cross-check program conducted by the Analytical Quality Control Service of the Office of Radiation Programs, Environmental Protection Agency (EPA). The technical experiment results confirmed this value.

Tritium is a radionuclide that is becoming of increasing concern to the general population. Since the advent of nuclear testing and construction and operation of nuclear power plants and nuclear fuel reprocessing plants, tritium has been introduced into the environment in greater quantities. As a result many Federal, State, local and private agencies have begun analyses of this radionuclide on a routine basis, while others are preparing for this capability. Reactor effluents, municipal water supplies, and rivers near nuclear power reactors and reprocessing plants are among the major environmental media for examination. A procedure of quality control to assist the laboratories in producing accurate and comparable data is necessary. Also this quality control service can help assess the equipment and sample preparation capabilities of the various laboratories.

The Analytical Quality Control Service (AQCS) has attempted to assist in this endeavor by establishing a standard deviation (σ) for tritium analyses and setting up control limits. From these criteria, a laboratory can judge its performance in various experiments and take appropriate corrective action if needed.

This paper describes the procedure for determining a standard deviation for tritium and the results of a technical experiment for validating σ.

Experimental procedure

For the past 2 years, the AQCS has been conducting a tritium cross-check water program with the three EPA laboratories and two other agencies interested in this analysis. The technical experiment consisted of triplicate analyses by each of the participating laboratories on three water samples containing known concentrations (not disclosed to the laboratories) of tritium.

Water samples (A, B, and C) were prepared by adding calibrated solutions of tritium to three 1-liter portions of distilled water. Cobalt-60 was added to sample B as a low energy beta interference. The activity of each sample solution is shown in table 1.

[1] Analytical Quality Control Service, Environmental Protection Agency, presently located at the Northeastern Radiological Health Laboratory of the Public Health Service, 109 Holton Street, Winchester, Mass. 01890.

Table 1. Radioactivity of the sample solutions

Sample	Tritium[a] (nCi/liter)	Cobalt-60 (nCi/liter)
A	51.8	—
B	146.4	15.0
C	331.4	—

[a] The accuracy of the standards was within ± 2 percent.

The laboratories were sent 50 ml of each sample. They were instructed to perform triplicate analyses using their routine procedure and to forward these results to the AQCS. The AQCS determined the average of each laboratory's analyses and returned a listing of these averages to the laboratories. An example of this report for a particular month is shown in table 2.

Table 2. Tritium analysis—mean values for three determinations

Laboratory	Tritium concentration (nCi/liter)
A	160.7
B	170.0
C	173.7
D	183.0
E	170.0
Known	177.8
Range	22.3

Discussion

After a suitable amount of data was accumulated, a standard deviation value of 10 percent for a single determination was experimentally set by comparing each laboratory's values to the actual concentration in the sample and studying laboratory precision over an extended period of time (1½ years). This σ applied to all tritium values greater than 5 nCi/liter. Using a standard deviation value of 10 percent for a single determination, the control limits were calculated for the mean value of replicate tritium determinations as follows:

$$\pm\text{WL (Warning Level)} = 2\sigma_m$$
$$\pm\text{CL (Control Limit)} = 3\sigma_m$$

$$\sigma_m = \frac{\sigma}{\sqrt{N}} \qquad \ldots(1)$$

where:

σ_m = the effective standard deviation for the mean.
σ = the established standard deviation for a single determination (10 percent of the known), and
N = the number of replicate determinations.

These control limits were then applied to the AQCS cross-check program. A typical report is shown in table 3. Mean values deviating from the known value by an amount less than the warning level were considered acceptable. Those between warning level and control limit were conditionally acceptable. Mean values deviating from the known value by an amount greater than the control limit were considered unacceptable, and an investigation should be made by the laboratories involved.

Table 3. Tritium analysis—control limits for three determinations

Laboratory	Tritium concentration mean value (nCi/liter)
A	47.3
B	46.4
C	47.0
D	47.1
E	54.0
F	53.3
Known	50.4
± WL	5.8
± CL	8.7

In order to test the standard deviation for the mean value, a technical experiment was conducted in cooperation with 16 participants including the EPA laboratories. Results of the experiment were compared to known values by the use of control charts as shown in figure 1.

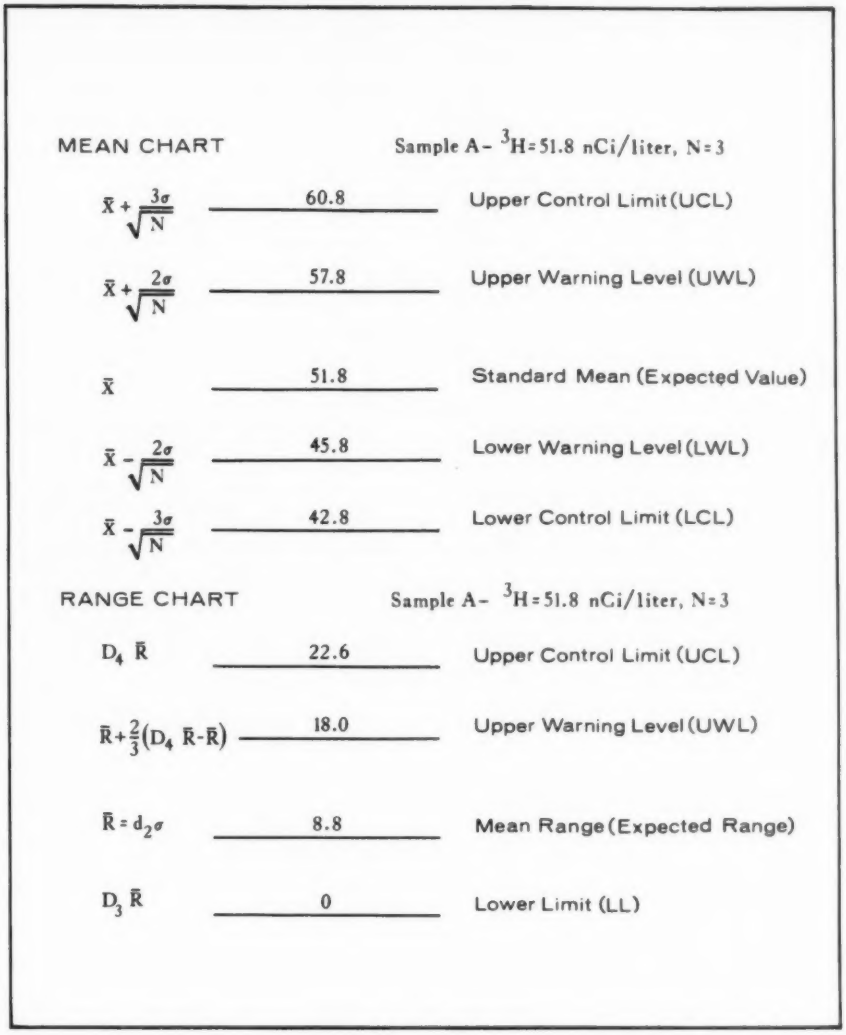
MEAN CHART
Sample A- ^{3}H=51.8 nCi/liter, N=3
$\bar{X} + \frac{3\sigma}{\sqrt{N}}$ 60.8 Upper Control Limit (UCL)
$\bar{X} + \frac{2\sigma}{\sqrt{N}}$ 57.8 Upper Warning Level (UWL)
$\bar{X}$ 51.8 Standard Mean (Expected Value)
$\bar{X} - \frac{2\sigma}{\sqrt{N}}$ 45.8 Lower Warning Level (LWL)
$\bar{X} - \frac{3\sigma}{\sqrt{N}}$ 42.8 Lower Control Limit (LCL)
RANGE CHART
Sample A- ^{3}H=51.8 nCi/liter, N=3
$D_4\ \bar{R}$ 22.6 Upper Control Limit (UCL)
$\bar{R} + \frac{2}{3}(D_4\ \bar{R} - \bar{R})$ 18.0 Upper Warning Level (UWL)
$\bar{R} = d_2\sigma$ 8.8 Mean Range (Expected Range)
$D_3\ \bar{R}$ 0 Lower Limit (LL)

Figure 1. Examples of "Mean and Range Control Charts"-
d_2, D_3, and D_4 are values taken from standard statistical tables prepared for the construction of range control charts and based on the value of N

The mean values were used for the data analyses because the range values did not vary significantly between laboratories and were well within the warning levels. All laboratory mean values were included. The data are presented in figures 2 to 4.

Analysis of data for precision was accomplished by comparing the standard deviation of each laboratory's individual results for each sample with the 10 percent standard deviation values established by the AQCS as shown in table 4.

Table 4. Data analysis of technical experiment-precision

Sample	Known σ and (percent)	Laboratory σ[a] and (percent)
A	5.18 (10)	7.7 (14)
B	14.6 (10)	25.1 (16)
C	33.1 (10)	56.0 (16)

[a] $\sigma = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{N-1}}$

where: N = number of laboratories,
$\bar{x}$ = average of sample activity of all analyses,
x_i = individual laboratory results.

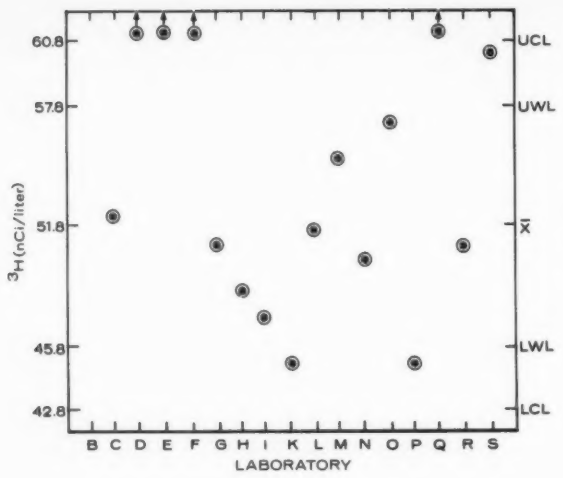

Figure 2. "Mean Chart," sample A, 51.8 nCi/liter, N = 3

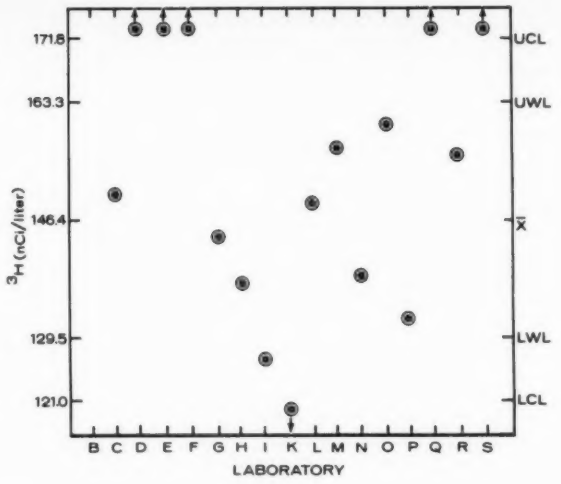

Figure 3. "Mean Chart," sample B, 146.4 nCi/liter, N = 3

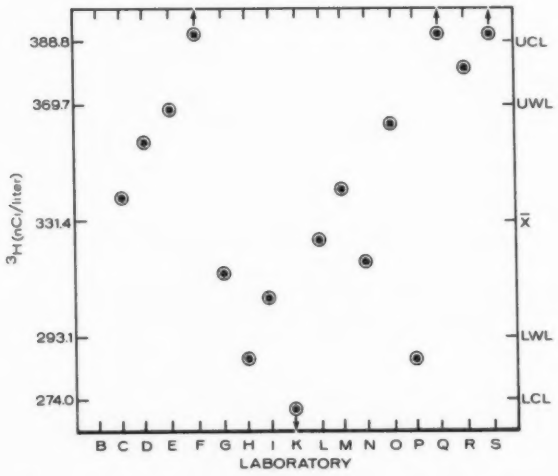

Figure 4. "Mean Chart," sample C, 331.4 nCi/liter, N = 3

To determine the accuracy of the tritium procedures, the difference between the mean values and the known values was compared to the established standard deviation for a single determination and for three determinations. The results are shown in tables 5 and 6.

Table 5. Data analysis of technical experiment

Sample	Amount present (nCi/liter)	Average of means (nCi/liter)
A	51.8	54.3
B	146.4	154.7
C	331.4	342.5

Table 6. Data analysis of technical experiment—accuracy

Sample	Difference (nCi/liter)	Percent[a]	σ[b] (nCi/liter)	σ_m[c] (nCi/liter)
A	2.5	4.8	5.18	3.0
B	8.3	5.7	14.6	8.4
C	11.1	3.3	33.1	19.1

[a] Percent = $\frac{\text{difference}}{\text{average amount present}}$

[b] σ = standard deviation for tritium, single determination (10 percent)

[c] σ_m = standard deviation for tritium, three determinations $\left(\frac{\sigma}{\sqrt{N}}\right)$

Conclusions

The calculated σ for the three samples is larger than the one established for tritium in the precision analysis (table 4) because a few participants had values differing from the known greatly in excess of the control limits. The data were recalculated excluding three laboratories, and the value came close to 10 percent. (A = 10.5, B = 11.2, C = 11.4). The relative σ does not seem to be dependent upon sample activity.

The analysis of accuracy (table 6) shows that the percent difference between the average amount present and average amount found is comparable to the established standard deviation. In some cases, these values are much better than expected.

From the data shown in the tables and figures, it appears that the established 10 percent standard deviation is valid. Values lower than 50 nCi/liter (25–30 nCi/liter) have been used in the cross-check program with similar results. Levels nearer 1–5 nCi/liter will be investigated in future studies, as some laboratories in the program routinely count samples at these lower levels. Due to the greater influence of background at 5 nCi/liter or less, the 10 percent standard deviation will have to be revised upward.

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SECTION I. MILK AND FOOD

Milk Surveillance, April 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk,

Figure 1. Milk sampling networks in the Western Hemisphere

calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 $\pm$ 0.08 g/liter for calcium and 1.51 $\pm$ 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, io-

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium 89: High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

dine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or samplir g areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environment conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for April 1971 and the 12-month period, May 1970 to

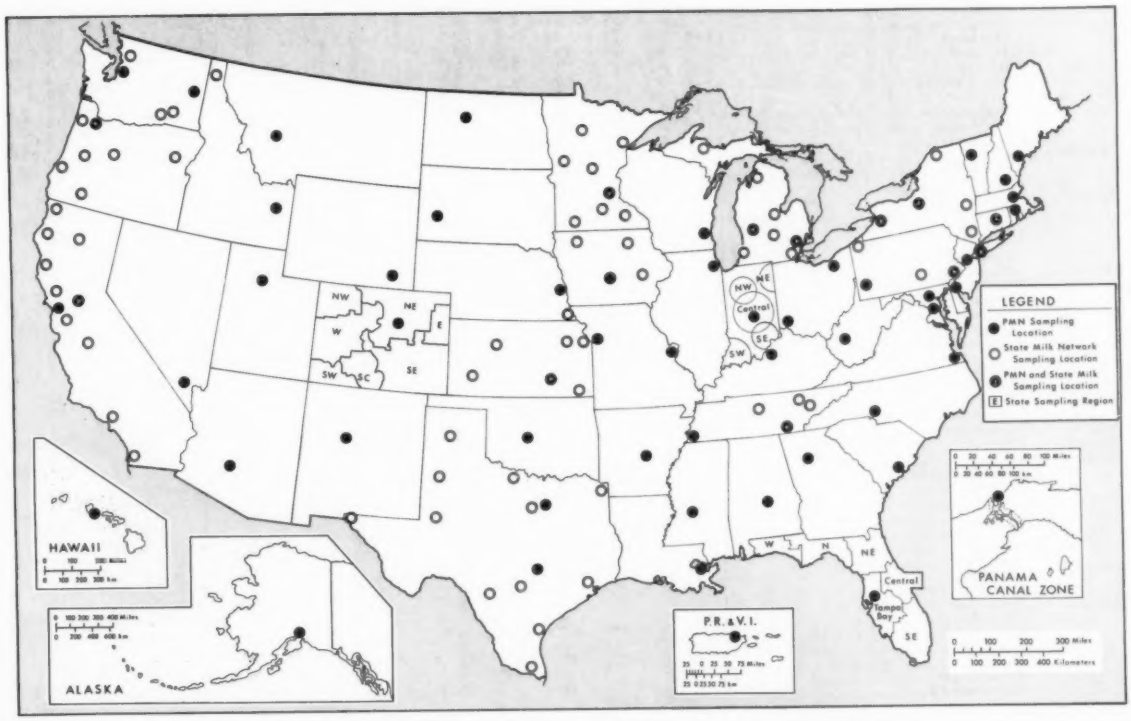

Figure 2. State and PMN milk sampling locations in the United States

Table 2. Concentrations of radionuclides in milk for April 1971 and 12-month period, May 1970 through April 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	8	6	0	0	12	9
Alaska:	Palmer[c]	P	3	5	0	0	20	13
Ariz:	Phoenix[c]	P	0	1	0	0	0	0
Ark:	Little Rock[c]	P	14	13	0	0	30	12
Calif:	Sacramento[c]	P	2	1	0	0	0	0
	San Francisco[c]	P	5	2	0	0	0	0
	Del Norte	P	24	17	0	0	21	11
	Fresno	P	0	2	0	0	0	1
	Humboldt	P	3	4	0	0	NA	4
	Los Angeles	P	2	2	0	0	0	1
	Mendocino	P	17	4	0	0	0	1
	Sacramento	P	3	3	0	0	0	1
	San Diego	P	2	2	0	0	0	1
	Santa Clara	P	0	2	0	0	0	0
	Shasta	P	3	3	0	0	0	2
	Sonoma	P	5	3	0	0	9	2
Colo:	Denver[c]	P	5	5	0	0	14	2
	West	R	(d)		<0	<0	<0	<0
	Northeast	R	(d)		NS	<0	NS	<0
	East	R	(d)		NS	<0	NS	<0
	Southeast	R	(d)		<0	<0	<0	<0
	South Central	R	(d)		NS	NS	NS	NS
	Southwest	R	(d)		NS	<0	NS	<4
	Northwest	R	(d)		<0	<5	<0	<0
Conn:	Hartford[c]	P	6	8	0	0	16	13
	Central	P	7	7	0	0	10	15
Del:	Wilmington[c]	P	8	9	0	0	11	8
D.C:	Washington[c]	P	9	7	0	0	18	10
Fla:	Tampa[c]	P	4	5	0	0	31	50
	West	R	6	9	0	0	20	18
	North	R	6	10	0	0	22	26
	Northeast	R	6	7	0	0	19	34
	Central	R	4	6	0	0	23	48
	Tampa Bay area	R	6	6	0	0	45	46
	Southeast	R	5	7	0	1	27	79
Ga:	Atlanta[c]	P	11	12	0	0	17	14
Hawaii:	Honolulu[c]	P	0	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	5	5	0	0	0	8
Ill:	Chicago[c]	P	6	7	0	0	12	12
Ind:	Indianapolis[c]	P	8	8	0	0	14	8
	Northeast	P	10	10	0	0	20	14
	Southeast	P	9	11	0	0	20	12
	Central	P	8	9	0	5	15	10
	Southwest	P	12	13	0	0	5	9
	Northwest	P	10	11	0	0	15	12
Iowa:	Des Moines[c]	P	NA	6	0	0	0	3
	Iowa City	P	10	8	0	0	12	13
	Des Moines	P	6	8	0	0	15	12
	Spencer	P	NS	NS	NS	NS	NS	NS
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[c]	P	7	7	0	0	0	3
	Coffeyville	P	7	9	14	3	21	6
	Dodge City	R	5	5	0	0	0	2
	Falls City	P	NS	12	NS	3	NS	8
	Hays	P	7	12	0	2	11	4
	Kansas City	P	7	8	22	5	26	12
	Topeka	P	7	10	0	0	15	9
	Wichita	P	9	12	0	0	0	4
Ky:	Louisville[c]	P	9	10	0	0	11	4
La:	New Orleans[c]	P	NS	14	NS	0	NS	19
Maine:	Portland[c]	P	9	10	0	0	22	22
Md:	Baltimore[c]	P	7	8	0	0	0	7
Mass:	Boston[c]	P	8	10	0	0	15	22
Mich:	Detroit[c]	P	8	8	0	0	16	11
	Grand Rapids[c]	P	9	9	0	0	18	14
	Bay City	P	NS	7	NS	<0	NS	12
	Charlevoix	P	11	12	<0 (2)	<1	17 (2)	15
	Detroit	P	6	8	<0	<0	17	8
	Grand Rapids	P	10	9	<0	<0	20	9
	Lansing	P	NA	9	<0 (2)	<0	11 (2)	14
	Marquette	P	7	12	<0 (2)	<0	27 (2)	23
	Monroe	P	9	6	<0 (2)	<0	8 (2)	4
	South Haven	P	5	8	<0 (3)	<0	16 (3)	6
Minn:	Minneapolis[c]	P	7	10	0	0	19	13
	Bemidji	P	4	7	0	0	20	21
	Mankato	P	7	5	0	0	13	11
	Rochester	P	7	8	0	0	16	16
	Duluth	P	17	15	0	0	28	28
	Worthington	P	6	4	0	0	0	0
	Minneapolis	P	11	11	0	0	14	14

See footnotes at end of table.

Table 2. Concentration of radionuclides in milk for April 1971 and 12-month period, May 1970 through April 1971—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
Minn:	Fergus Falls	P	7	6	0	0	13	15
	Little Falls	P	17	13	0	0	25	35
Miss:	Jackson[c]	P	14	12	0	0	13	10
Mo:	Kansas City[c]	P	6	8	0	0	14	4
	St. Louis[c]	P	8	9	0	0	0	4
Mont:	Helena[c]	P	5	5	0	0	0	9
Nebr:	Omaha[c]	P	8	5	0	0	0	1
Nev:	Las Vegas[c]	P	0	2	0	0	0	0
N.H:	Manchester[c]	P	7	9	0	0	21	22
N.J:	Trenton[c]	P	10	9	0	0	14	12
N. Mex:	Albuquerque[c]	P	0	3	0	0	0	0
N.Y:	Buffalo[c]	P	8	8	0	0	22	13
	New York City[c]	P	8	10	0	0	14	18
	Syracuse[c]	P	6	7	0	0	20	11
	Albany	P	8	9	0 (4)	0	21 (4)	*0
	Massena	P	7	8	0 (2)	0	21 (2)	25
	Newburg	P	4	8	0 (4)	0	*0 (4)	*0
	New York City	P	11	10	0	0	22	*0
	Syracuse	P	*0	4	0 (2)	0	*0 (2)	*0
N.C:	Charlotte[c]	P	10	11	0	0	17	12
N. Dak:	Minot[c]	P	8	9	0	0	11	10
Ohio:	Cincinnati[c]	P	7	8	0	0	0	3
	Cleveland[c]	P	7	8	0	0	12	12
Okla:	Oklahoma City[c]	P	6	6	0	0	0	6
Oreg:	Portland[c]	P	6	5	0	0	15	4
	Baker	P	NA	4	*0	*0	*0	9
	Coos Bay	P	NA	7	*0	*0	24	13
	Eugene	P	NA	3	*0	*0	*0	1
	Medford	P	NA	3	*0	*0	*0	9
	Portland composite	P	NA	6	*0	*0	*0	6
	Portland local	P	NA	5	*0	*0	9	8
	Redmond	P	NA	3	*0	*0	25	2
	Tillamook	P	NA	7	*0	*0	*0	15
Pa:	Philadelphia[c]	P	7	9	0	0	12	8
	Pittsburgh[c]	P	11	11	0	0	11	16
	Dauphin	P	10	8	0	1	14	13
	Erie	P	NS	11	NS	0	NS	26
	Philadelphia	P	8	9	0	0	11	15
	Pittsburgh	P	14	12	0	1	19	21
R.I:	Providence[c]	P	7	9	0	0	19	19
S.C:	Charleston[c]	P	9	9	0	1	0	15
S. Dak:	Rapid City[c]	P	NS	7	NS	0	NS	5
Tenn:	Chattanooga[c]	P	7	9	0	0	13	9
	Memphis[c]	P	7	8	0	0	14	8
	Chattanooga	P	NA	9	0	0	23	16
	Clinton	P	NA	10	0	0	21	17
	Fayetteville	P	NA	11	0	0	24	15
	Knoxville	P	NA	7	0	0	20	14
	Nashville	P	NA	6	0	0	18	11
Tex:	Austin[c]	P	3	2	0	0	0	2
	Dallas[c]	P	8	7	0	0	0	5
	Amarillo	R	NS	4	0	0	0	5
	Corpus Christi	R	NS	3	0	0	0	0
	El Paso	R	NS	3	0	0	0	2
	Fort Worth	R	NS	4	0	0	0	0
	Harlingen	R	NS	2	0	0	0	0
	Houston	R	9	6	0	0	15	18
	Lubbock	R	NS	3	0	0	0	0
	Midland	R	2	2	0	0	0	0
	San Antonio	R	NS	3	0	0	0	0
	Texarkana	R	NS	NS	NS	NS	NS	NS
	Tyler	R	18	14	0	0	10	15
	Uvalde	R	NS	2	0	0	0	0
	Wichita Falls	R	NS	8	0	0	0	0
Utah:	Salt Lake City[c]	P	4	4	0	0	21	13
Vt:	Burlington[c]	P	6	7	0	0	0	14
Va:	Norfolk[c]	P	7	9	0	0	0	8
Wash:	Seattle[c]	P	4	5	0	0	0	3
	Spokane[c]	P	5	5	0	0	0	1
	Benton County	R	NS	1	NS	0	NS	2
	Franklin County	R	3	3	0	0	10	3
	Sandpoint, Idaho	R	9	11	0	0	17	22
	Skagit County	R	8	7	0	0	13	11
W. Va:	Charleston[c]	P	8	8	0	0	14	7
Wisc:	Milwaukee[c]	P	6	6	0	0	14	13
Wyo:	Laramie[c]	P	7	5	0	0	0	1
CANADA:								
Alberta:	Calgary	P	(d)		(d)		18	18

See footnotes at end of table.

Table 2. Concentration of radionuclides in milk for April 1971 and 12-month period, May 1970 through April 1971—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued							
Edmonton	P	(d)		(d)		24	21
British Columbia: Vancouver	P	(d)		(d)		19	24
Manitoba: Winnipeg	P	(d)		(d)		26	25
New Brunswick: Fredericton	P	(d)		(d)		24	24
Newfoundland: St. John's	P	(d)		(d)		17	32
Nova Scotia: Halifax	P	(d)		(d)		21	21
Ontario: Ottawa	P	(d)		(d)		14	16
Sault Ste. Marie	P	(d)		(d)		27	33
Ontario: Thunder Bay	P	(d)		(d)		17	32
Toronto	P	(d)		(d)		11	11
Windsor	P	(d)		(d)		11	11
Quebec: Montreal	P	(d)		(d)		19	19
Quebec	P	(d)		(d)		30	29
Saskatchewan: Regina	P	(d)		(d)		17	14
Saskatoon	P	(d)		(d)		17	18
CENTRAL AND SOUTH AMERICA:							
Colombia: Bogota	P	2	1	0	0	0	0
Chile: Santiago	P	0	0	0	0	0	0
Ecuador: Guayaquil	P	0	0	0	0	0	0
Jamaica: Kingston	P	NS	5	NS	0	NS	81
Venezuela: Caracas	P	0	1	0	0	0	0
Canal Zone: Cristobal[c]	P	NS	2	NS	0	NS	10
Puerto Rico: San Juan[c]	P	4	4	0	0	21	9
PMN network average[f]			7	0	0	10	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclides concentrations for the Pasteurized Milk Network stations denoted by footnote [c].

NA, no analysis.
NS, no sample collected.

April 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for April 1971 were below the respective practical reporting levels. The following station averages reflect samples in which strontium-89 was detected: Calif., San Francisco, 13 pCi/liter, Del Norte, 26 pCi/liter, Humboldt, 7 pCi/liter, Mendocino, 48 pCi/liter, Sonoma, 20 pCi/liter; Kans., Coffeyville, 11 pCi/liter, Dodge City, 9 pCi/liter, Kansas City, 6 pCi/liter, Topeka, 9 pCi/liter. Barium-140 was detected at Coffeyville, and Kansas City, Kans., 11 pCi/liter, respectively.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 24 pCi/liter in the United States for April 1971, and the highest 12-month average was 17 pCi/liter (Del Norte, Calif.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged

from 0 to 45 pCi/liter in the United States for the month of April 1971, and the highest 12-month average was 79 pCi/liter (Southeast Florida), representing 2.2 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Kansas, Kansas City (State), 14 pCi/liter.

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Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. *Programs reported in Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 in Total Diet and Milk	July–December 1970	May 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	October–December 1970 and Annual Summary 1970	May 1971
Strontium-90 in Tri-City Diets	January–December 1969	June 1970

XUM

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2–4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1970	July 1971
Kansas	January–December 1969	September 1970
Minnesota	July–December 1969	May 1971
North Carolina	January–December 1967	May 1969
New York	January–June 1969	June 1970
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	January–March 1971	July 1971
Washington	July 1968–June 1969	February 1971

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
Fallout in the United States and other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	July–December 1970	June 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1968	April 1971

XUM

1. Radiation Alert Network April 1971

Office of Air Programs
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of these stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A complication of the daily field estimates is available upon request from the Data Aquisition and Analysis Branch, Division of Air Quality and Emission Data, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during April 1971. All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, April 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Precipitation			
							Total depth (mm)	Field estimation of deposition		
			Maximum	Minimum	Average[a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	6	0	2	4	181	4	181	75
Alaska:	Adak	1	0	0	0	0				
	Anchorage	30	0	0	0	0				
	Attu Island	0				0				
	Fairbanks	13	3	1	2	7	105	6	85	0
	Juneau	4	0	0	0	0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	13	5	1	3	0				
Ark:	Little Rock	6	2	1	1	0				
Calif:	Berkeley	22	1	0	0	3	22	3	22	0
	Los Angeles	22	4	0	1	0				
C.Z:	Ancon	15	0	0	0	0				
Colo:	Denver	22	5	1	2	6	53	[b]		
Conn:	Hartford	21	1	0	0	7	61	7	61	2
Del:	Dover	21	2	0	1	0				
D.C:	Washington	25	2	0	1	0				
Fla:	Jacksonville	22	2	1	1	5	64	3	24	1
	Miami	21	1	0	1	1	7	1	7	0
Ga:	Atlanta	20	2	1	1	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	25	1	0	0	4	69	[b]		
Idaho:	Boise	22	4	1	2	3	11	3	11	1
Ill:	Springfield	4	2	1	1	0				
Ind:	Indianapolis	21	2	0	1	0				
Iowa:	Iowa City	18	6	1	2	2	18	2	18	4
Kans:	Topeka	21	4	1	2	6	26	6	26	2
Ky:	Frankfort	0				0				
La:	New Orleans	17	1	0	1	3	23	[b]		
Maine:	Augusta	21	1	0	0	6	53	5	40	0
Md:	Baltimore	21	2	0	1	4	28	4	28	0
Mass:	Lawrence	21	1	0	0	6	55	6	55	1
	Winchester	22	1	0	1	6	77	6	77	0
Mich:	Lansing	21	1	0	1	5	30	5	30	7
Minn:	Minneapolis	22	3	0	1	5	38	5	38	12
Miss:	Jackson	18	2	0	1	5	242	5	242	4
Mo:	Jefferson City	21	4	1	2	4	19	4	19	4
Mont:	Helena	20	3	1	1	1	7	1	7	0
Nebr:	Lincoln	21	10	1	4	1	8	1	8	0
Nev:	Las Vegas	21	3	1	2	0				
N.H:	Concord	0				0				
N.J:	Trenton	22	2	0	1	3	66	3	66	5
N. Mex:	Santa Fe	14	2	1	1	3	34	3	34	4
N.Y:	Albany	20	1	0	0	0				
	Buffalo	19	2	0	1	0				
	New York City	0				0				
N.C:	Gastonia	16	11	0	3	3	41	[b]		
N. Dak:	Bismarck	21	4	0	2	5	38	5	38	4
Ohio:	Cincinnati	10	4	0	2	0				
	Columbus	5	3	1	2	0				
	Painesville	22	3	0	1	8	37	8	37	4
Okla:	Oklahoma City	0				0				
	Ponca City	21	8	1	2	6	92	6	92	1
Oreg:	Portland	22	1	0	0	11	90	11	90	7
Pa:	Harrisburg	18	3	0	1	0				
P.R:	San Juan	0				0				
R.I:	Providence	20	2	0	1	0				
S.C:	Columbia	21	2	0	1	4	110	4	110	1
S. Dak:	Pierre	20	6	1	2	0				
Tenn:	Nashville	14	3	0	1	6	78	6	78	8
Tex:	Austin	0				0				
	El Paso	0				0				
Utah:	Salt Lake City	30	4	0	1	8	129	8	129	51
Vt:	Barre	0				0				
Va:	Richmond	22	2	0	1	2	20	2	20	2
Wash:	Seattle	9	0	0	0	3	46	[b]		
	Spokane	18	2	0	1	0				
W. Va:	Charleston	20	5	1	2	5	30	5	30	8
Wisc:	Madison	18	3	0	1	8	85	8	85	24
Wyo:	Cheyenne	21	6	0	2	6	69	6	69	24
Network summary		1,080	11	0	1	175	68	5	58	8

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program,[1] April 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for April 1971 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, April 1971

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.2	0.1	0.2	33	0.59
Coral Harbour	4	.3	.1	.2	154	1.95
Edmonton	4	.4	.4	.4	413	2.63
Ft. Churchill	4	.2	.1	.1	80	1.53
Fredericton	4	.3	.1	.2	74	6.21
Goose Bay	4	.2	.1	.2	40	2.81
Halifax	27	.2	.1	.1	117	17.39
Inuvik	4	.2	.1	.1	93	.85
Montreal	4	.2	.1	.2	207	9.39
Moosonee	4	.3	.2	.3	58	2.10
Ottawa	4	.3	.2	.3	159	7.60
Quebec	4	.2	.0	.1	209	7.06
Regina	4	.4	.2	.3	291	6.41
Resolute	4	.2	.2	.2	109	1.24
St. John's, Nfld	4	.2	.1	.1	143	27.54
Saskatoon	4	.2	.2	.2	491	10.20
Sault Ste. Marie	4	.4	.1	.3	167	5.03
Thunder Bay	4	.2	.1	.2	252	6.27
Toronto	4	.3	.1	.2	291	8.13
Vancouver	4	.2	.1	.2	104	5.27
Whitehorse	4	.4	.1	.2	125	.73
Windsor	4	.2	.1	.2	82	2.45
Winnipeg	4	.3	.1	.2	314	18.84
Yellowknife	4	.1	.0	.1	NS	NS
Network summary	119	0.4	0.0	0.2	174	6.62

NS, no sample.

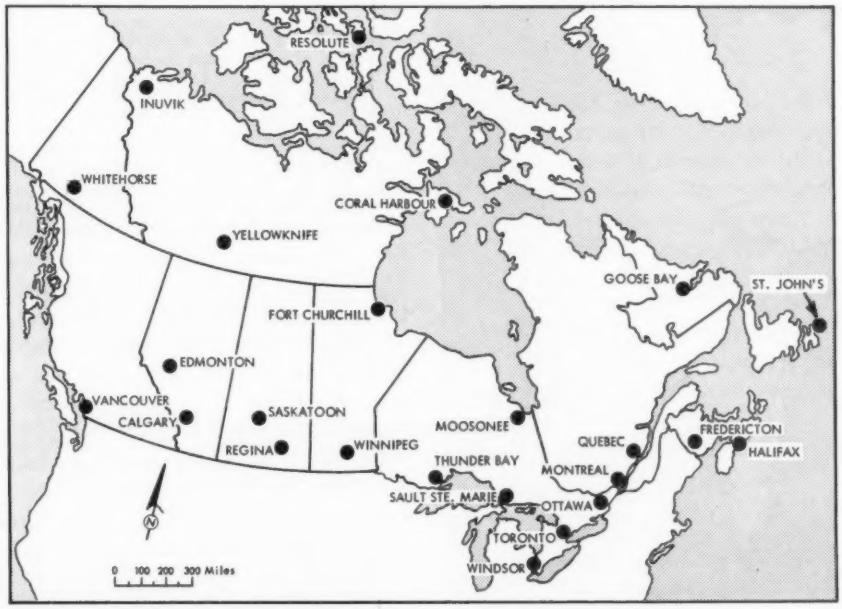

Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program April 1971

Pan American Health Organization and *Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The April 1971 air monitoring results from the participating countries are given in table 3.

Table 3. Summary of gross beta radioactivity in Pan American surface air, April 1971

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	19	0.17	0.01	0.04
Chile:	Santiago	30	.40	.03	.19
Colombia:	Bogota	19	.18	.01	.05
Ecuador:	Cuenca	0			
	Guayaquil	11	.21	.07	.10
	Quito	0			
Guyana:	Georgetown	8	.90	.12	.34
Jamaica:	Kingston	0			
Peru:	Lima	17	.13	.03	.07
Venezuela:	Caracas	7	.92	.19	.43
West Indies:	Trinidad	16	.94	.20	.51
Pan American summary		127	.94	.01	.19

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Figure 3. Pan American Air Sampling Program stations

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(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Oak Ridge Area and Savannah River Plant.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Oak Ridge Area[2] July-December 1969

Union Carbide Nuclear Company
Oak Ridge, Tenn.

Oak Ridge area is a complex made up primarily of the Y-12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ability to fix radioactive materials by an ion exchange mechanism. Liquid wastes which contain long-lived fission products are confined in storage tanks or are concentrated by evaporation and disposed of in deep wells. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

[2] Summarized from Environmental Levels of Radioactivity for the Oak Ridge area, (Report Period July–December 1969). Health Physics and Safety Section, Health Physics Division, Oak Ridge National Laboratory.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations which encircle the plant areas (figure 1) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of eight stations encircling the Oak Ridge area at distances of from 12 to 75 miles (figure 2). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average radioactivity concentrations are presented in tables 1 and 2. Airborne radioactive iodine is monitored in the immediate environment

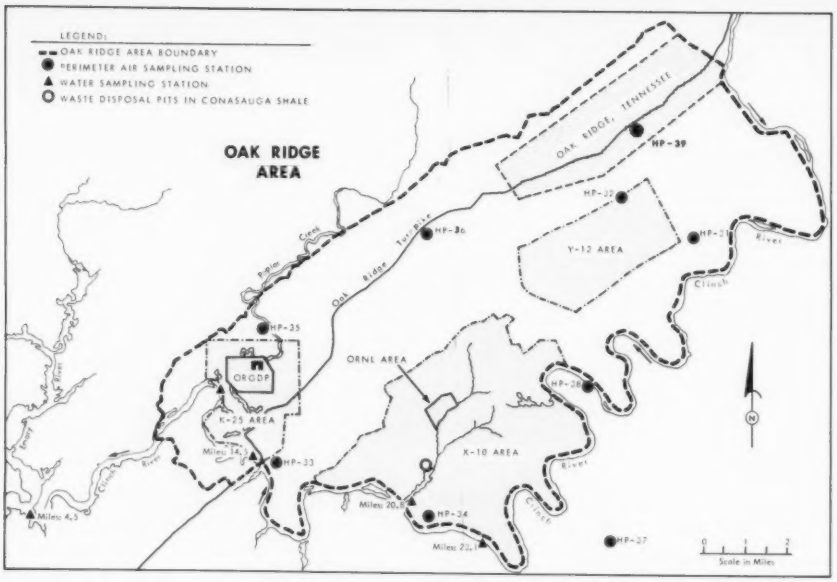

Figure 1. Oak Ridge area, environmental sampling locations

of the plant areas by passing air through a cartridge containing activated charcoal.

During the July–December 1969 surveillance period, 233 samples were collected from perimeter monitoring stations and analyzed for iodine-131. Of these, the maximum concentration detected was 0.15 pCi/m³, the minimum was less than 0.01 pCi/m³, and the average was 0.01 pCi/m³. The radiation protection standard specified in the AEC Manual for iodine-131 in the ambient atmosphere in uncontrolled areas is 100 pCi/m³.

Milk monitoring

Raw milk is monitored for iodine-131 and strontium-90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge area. Four stations, located more remotely with respect to the Oak Ridge operations, are sampled at a rate of one station each week. The purpose of the milk

Table 1. Long-lived gross beta radioactivity of particulates in air, Oak Ridge Area, July–December 1969

Perimeter stations						Remote stations					
Station number (figure 1)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]	Station number (figure 2)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]
		Maximum	Minimum	Average				Maximum	Minimum	Average	
HP-31	25	0.43	0.032	0.16	0.16	HP-51	26	0.42	0.047	0.16	0.16
HP-32	26	.53	.025	.19	.19	HP-52	25	.50	.035	.17	.17
HP-33	26	.35	<.001	.12	.12	HP-53	26	.49	.008	.16	.16
HP-34	26	.43	.038	.14	.14	HP-54	25	.42	.035	.15	.15
HP-35	26	.44	.042	.16	.16	HP-55	25	.32	.013	.11	.11
HP-36	[b]119	.43	.019	.18	.18	HP-56	26	.55	.021	.17	.17
HP-37	26	.39	.007	.16	.16	HP-57	26	.46	.038	.16	.16
HP-38	26	.43	.035	.16	.16	HP-58	23	.49	.030	.19	.19
HP-39	26	.57	.040	.19	.19						
Summary	326	0.57	<0.001	0.16	0.16	Summary	202	0.55	0.008	0.16	0.16

[a] The applicable AEC Radiation Protection Standard is 100 pCi/m³.
[b] Sample frequency—5 days per week.

XUM

Table 2. Long-lived gross alpha radioactivity of particulates in air, Oak Ridge Area, July–December 1969

Perimeter stations						Remote stations					
Station number (figure 1)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]	Station number (figure 2)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]
		Maximum	Minimum	Average				Maximum	Minimum	Average	
HP-31	25	0.006	<0.001	0.002	0.10	HP-51	26	0.003	<0.001	0.001	0.05
HP-32	26	.008	< .001	.002	.10	HP-52	25	.005	< .001	.002	.10
HP-33	26	.005	< .001	.002	.10	HP-53	26	.004	< .001	.001	.05
HP-34	26	.003	< .001	.001	.05	HP-54	25	.004	< .001	.001	.05
HP-35	26	.008	< .001	.002	.10	HP-55	25	.003	< .001	.001	.05
HP-36	[b]119	.025	< .001	.005	.25	HP-56	26	.004	< .001	.001	.05
HP-37	26	.005	< .001	.002	.10	HP-57	26	.004	< .001	.001	.05
HP-38	26	.003	< .001	.001	.05	HP-58	24	.006	< .001	.002	.10
HP-39	26	.008	< .001	.002	.10						
Summary	326	0.025	<0.001	0.002	0.10	Summary	203	0.006	<0.001	0.001	0.05

[a] The applicable AEC Radiation Protection Standard for natural uranium in air is 2 pCi/m³.
[b] Sample frequency—5 days per week.

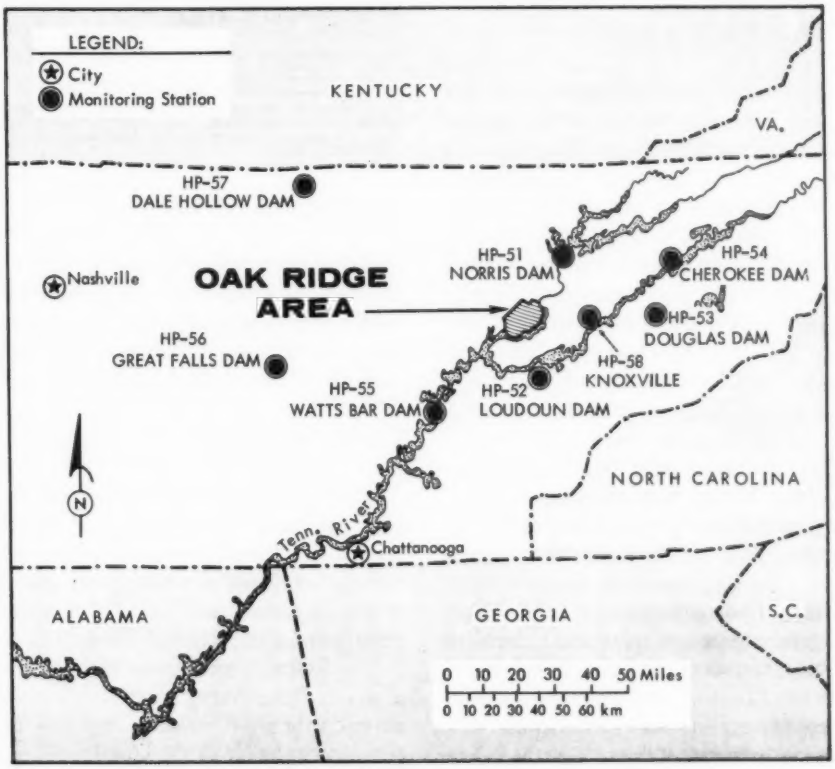

Figure 2. Remote air monitoring stations, Oak Ridge area

sampling program is twofold: first, samples collected in the immediate vicinity of the Oak Ridge area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples. The concentrations of iodine-131 and strontium-90 detected in raw milk samples during the period are given in table 3.

Table 3. Radionuclides in raw milk, Oak Ridge area July–December 1969

Radionuclide and location	Concentration (pCi/liter)		
	Maximum	Minimum[a]	Average
Iodine-131			
Immediate environs	48	<10	<10
Remote environs	<10	<10	<10
Strontium-90			
Immediate environs	32	2.0	15
Remote environs	22	5.4	15

[a] The minimum detectable concentrations of iodine-131 and strontium-90 in milk are 10 pCi/liter and 2 pCi/liter, respectively. In averaging, one-half of the minimum detectable concentration was used for all samples showing an activity less than this concentration.

Water monitoring

Large volume, low-level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River system by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y-12 Plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that resulting average concentrations in the Clinch River comply with AEC radiation protection standards. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tenn. Stream gauging operations are carried on continuously to obtain dilution factors for calculating the probable concentrations of wastes in the river. Samples are analyzed for the long-lived beta-particle emitters, uranium, and the transuranic alpha-particle emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold-up time in the waste effluent system are such that short-lived radionuclides are normally not present. The average concentrations of major radionuclides in the Clinch River are given in table 4 for the period from July–December 1969.

Two quarterly composite water samples from the Clinch River were analyzed for uranium during this period. For these samples, the uranium concentrations were less than 1 pCi/liter, the level of detectability. The AEC radiation protection standard for natural uranium in water released to unrestricted areas is 20 nCi/liter.

Table 4. Concentrations of major radionuclides in the Clinch River, July–December 1969

Radionuclide	Average concentration (pCi/liter)		
	Location on Clinch River[a]		
	Mile: 23.1 (Upstream)	Mile: 20.8[b] (Outfall)	Mile: 4.5 (Downstream)
Strontium-90	1.3	0.8	0.7
Cerium-144	.2	<.1	<.1
Cesium-137	1.4	.2	1.2
Ruthenium-103-106	.4	.3	1.5
Cobalt-60	1.5	.1	.7
Zirconium-niobium-95	.3	<.1	.5
Tritium	NA	1,740	NA

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River (figure 1).
[b] The concentrations at Mile: 20.8 are not measured directly but the values are calculated based on the levels of waste released from White Oak Dam and the dilution provided by the Clinch River.
NA, no analysis.

Gamma measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above the ground. The results are shown in table 5.

Discussion of data

The average air contamination level for gross beta radioactivity, as shown by the continuous air monitoring filter data, for both the immediate and remote environs of the plants (figures 1 and 2) was 0.16 percent of the AEC radiation protection standard for uncontrolled areas.

The average air contamination levels for gross alpha radioactivity, as shown by the continuous air monitoring filter data, for the immediate and remote environs of the plants were 0.10 percent and 0.05 percent, respectively, of the AEC radiation protection standard for natural uranium for uncontrolled areas.

The average concentration of iodine-131 in air in the immediate environs of the plants was 0.01 pCi/m^3. This is approximately 0.01 percent of the AEC radiation standard for uncontrolled areas.

The average concentrations of iodine-131 in raw milk in the immediate and remote environs of the

Table 5. External gamma radiation levels,[a] Oak Ridge area, July–December 1969

Location	Radiation levels (mR/h)						
	July	August	September	October	November	December	Average
Kerr Hollow Gate	NA	0.012	0.012	0.010	0.012	0.013	0.012
Y-12, East Portal	NA	.011	.013	.011	NA	.018	.013
Newcomb Road	NA	.011	.012	.011	NA	.012	.012
Gallaher Gate	NA	.011	.010	.014	.019	.014	.014
White Wing Gate	NA	.011	.011	.010	.011	.011	.011

[a] The background in the Oak Ridge area, determined in 1943, was approximately 0.012 mR/h.
NA, no analysis.

Oak Ridge area were both less than 10 pCi/liter. These levels fall within the limits of FRC Range I if the average intake per individual is assumed to be 1 liter of milk per day.

The average concentration of strontium-90 in raw milk in both the immediate and remote environs of the controlled areas was 15 pCi/liter. The average falls within the limits of FRC Range I for transient rates of daily intake of strontium-90 for application to the average of suitable samples of an exposed population.

The percent maximum concentration of radioactivity in the Clinch River at Mile 20.8 (the point of entry of most of the wastes) and the measured average concentration at Mile 4.5 (near Kingston, Tenn.) were 0.39 percent and 0.25 percent, respectively, of the AEC radiation protection standards. The higher than normal concentration reported for radioactivity at Mile 23.1, Melton Hill Dam, was due primarily to cobalt-60. This contamination was found in the river upstream from the ORNL waste outfall and was the result of a source of contamination other than Oak Ridge operations. The average concentration of transuranic alpha particle emitters in the Clinch River at Mile 20.8 was 0.14 pCi/liter which is 0.14 percent of the AEC radiation protection standard for water containing a mixture of unknown radionuclides.

The average concentration of natural uranium materials in the Clinch River reflecting the effects of all Oak Ridge plants was less than 0.1 percent of the AEC radiation standard for uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge area was 0.012 mR/h, which is approximately the same as that level measured during the period prior to Oak Ridge operations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	January 1970
January–June 1969	May 1970

2. Savannah River Plant[3] July-December 1970

E. I. duPont de Nemours
Aiken, S.C.

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. duPont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Ga. Production facilities include a fuel preparation area, three reactors, two fuel separation areas, and a heavy water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

A continuous monitoring program has been maintained since 1951 (before plant startup) to determine the concentrations of radioactive materials in a 1,200-square mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale counties in South Carolina, and Richmond, Burke, and Screven counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared

[3] Summarized from "Effects of the Savannah River Plant on Environmental Radioactivity," Semiannual Report, July–December 1970 (DPST-10-30-1).

with the AEC radiation protection standards as given in the AEC Manual.

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity and atmospheric fallout are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during the report period.

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by biweekly analyses of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a circle of about 25 miles radius from the center of the plant (figure 3). Deposition rates of radioactive material at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne radioactivity by SRP would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Ga., and at Columbia and Greenville, S.C., are so distant from SRP that the effect of SRP operations is negligible; they serve as reference points for determining background radioactivity levels (figure 4). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between fallout and SRP releases.

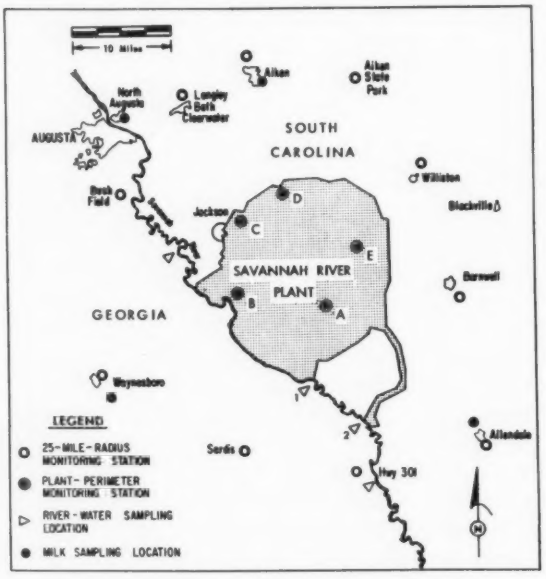

Figure 3. Environmental sampling locations, Savannah River Plant

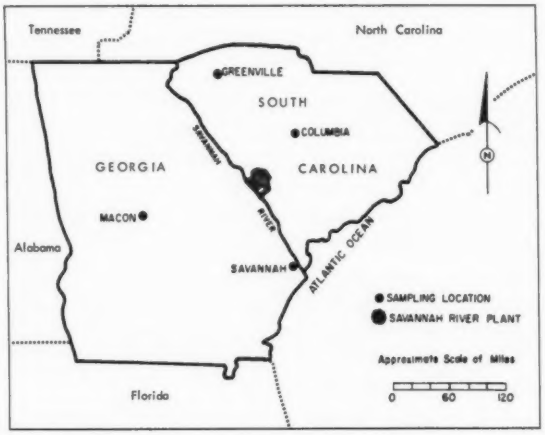

Figure 4. Distant air monitoring stations, Savannah River Plant

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fuel separation areas, was obscured by fallout. The influence of nuclear tests, which resumed in September 1961, is shown in figure 5. The present low levels of atmospheric activity are attributed to the moratorium on above ground nuclear tests, which began in 1962. The observed spring increases are anticipated and result primarily from the mixing of the stratospheric debris into the troposphere. The average beta concentration in air decreased from 0.26 pCi/m³ to 0.17 pCi/m³ during the last half of 1970. Gamma-emitting radionuclides in fallout were cesium-134–137, cerium-141–144, ruthenium-103–106, and zirconium-niobium-95.

Trace amounts of short radioactive-half-life materials were detected in routine air samples taken with a high volume air sampler. Nonplant origin of the radioactivity was indicated by the uniform levels found at all stations, both on and off the plant. The major component, beryllium-7, is a naturally occurring radionuclide formed by interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. Radioactivity in air, de-

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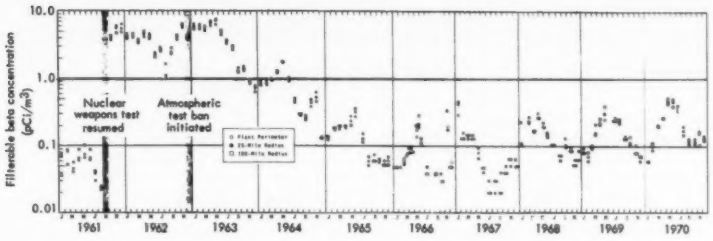

Figure 5. Influence of weapons tests

Table 6. Radioactivity in air, Savannah River Plant, July–December 1970

Sampling points	Alpha radioactivity[a] (fCi/m³)			Nonvolatile beta radioactivity[b] (pCi/m³)			Specific radionuclides in composite samples (pCi/m³)					
	Maximum	Minimum	Average	Maximum	Minimum	Average	$^{89, 90}$Sr	^{137}Cs	$^{141, 144}$Ce	$^{103, 106}$Ru	^{95}Zr-Nb	^{7}Be
Plant perimeter:												
A	1.3	0.4	0.7	0.51	0.10	0.18						
B	1.5	.4	.8	.66	.08	.14						
C	1.6	.4	.7	.61	.11	.19	0.005	0.01	0.07	0.07	0.14	0.18
D	1.3	.5	.8	.95	.09	.22						
E	1.8	.4	.6	.46	.10	.18						
Average			.7			.18						
25-mile radius:												
Aiken Airport	1.4	.4	.7	.52	.13	.20						
Aiken State Park	1.0	ND	.6	.46	.01	.16						
Allendale	3.0	.3	1.0	.41	.06	.17						
Barnwell	1.2	.3	.7	.46	.07	.18						
Bush Field	1.4	ND	.7	.56	.07	.17	.005	.01	.06	.05	.12	.16
Langley	1.7	.4	.7	.68	.09	.20						
Sardis	1.0	.3	.6	.47	.06	.18						
Waynesboro	1.3	.3	.6	.50	.09	.18						
Williston	1.3	.4	.7	.54	.08	.19						
Highway 301	1.4	ND	.6	.49	.11	.20						
Average			.7			.18						
Distant air-monitoring:												
S.C.												
Columbia	1.4	ND	.9	0.59	.05	.14						
Greenville	1.4	ND	.7	.58	.04	.18						
Ga.												
Macon	1.3	ND	.6	.52	.05	.15	.005	.01	.07	.34	.12	.18
Savannah	1.0	ND	.5	.47	.04	.16						
Average			.7			.16						

[a] AEC radiation protection standard-70 fCi/m³.
[b] AEC radiation protection standard-100 pCi/m³.
ND, nondetectable.

termined from filter analyses, is shown in table 6. The July–December 1970 concentrations of filterable beta radioactivity (0.17 pCi/m³) and alpha radioactivity (0.7 fCi/m³) in air were 0.17 and 1.0 percent of the respective AEC standards. Tritium oxide concentrations in air, at the plant perimeter and at the 25-mile radius stations, did not exceed 0.2 percent of the AEC standard.

Deposition of fallout during July–December 1970 averaged 17 nCi/m² at the plant perimeter locations and 15 nCi/m² at 25-mile radius locations; comparable values for the last half of 1969 were 13 and 12 nCi/m² (excluding naturally occurring beryllium-7). Deposition at each sampling location is presented in table 7.

Water monitoring

The plant site is drained by five streams that flow several miles through the reservation before reaching the river (figure 6). The primary sources of the very small amount of radioactivity that reaches the river are the reactor facilities. The reactors are cooled and moderated by heavy water which, in turn, is cooled by river water in heat exchangers. This arrangement prevents irradiation of the river water so that radioactivity is discharged into the river water only on the rare occasions when small quantities of moderator are lost by heat exchanger leaks.

The irradiated fuel (canned to prevent leaching of radionuclides) discharged from a reactor is stored in a large, water-filled basin that is purged

Table 7. Total fallout deposited, Savannah River Plant, July–December 1970

Sampling points	Radioactivity concentration (nCi/m²)								
	Alpha[a]	Strontium-89	Strontium-90	Cesium-137	Cerium-141, 144	Zirconium-niobium-95	Beryllium-7[b]	Iodine-131	Ruthenium-103–106
Plant perimeter:									
A	4.4	1.3	0.5	0.8	6.4	4.8	14.7	1.6	1.1
B	2.8	.2	.5	.7	4.9	1.7	14.0	1.0	.8
C	5.0	.6	.7	.8	6.5	4.9	21.5	.7	2.5
D	5.9	.7	.8	.9	8.3	7.6	21.6	1.2	2.6
E	5.0	.9	.8	.9	7.6	5.8	22.5	1.6	1.8
Average	4.6	.8	.7	.8	6.7	5.0	18.9	1.2	1.8
25-mile radius:									
Aiken Airport	1.7	1.1	.5	.8	5.5	3.9	19.8	1.0	1.6
Aiken State Park	3.7	.5	.7	.7	7.5	5.0	21.7	1.6	1.5
Allendale	4.5	.8	.6	.6	7.9	5.2	24.7	1.9	2.1
Barnwell	1.5	.3	.5	.4	1.0	2.7	3.0	ND	1.4
Bush Field	2.3	ND	.7	.8	6.1	5.2	14.5	.8	.8
Langley	4.5	.8	.5	.8	6.2	4.6	19.1	.8	2.0
Sardis	2.6	1.0	.6	1.0	7.1	9.3	19.1	1.0	2.1
Waynesboro	5.5	.7	.7	1.1	7.4	5.6	21.0	.9	1.3
Williston	2.0	.2	.3	.3	5.5	2.2	12.4	1.9	ND
Highway 301	2.4	1.4	.6	.8	4.6	4.6	13.3	1.0	ND
Average	8.0	.7	.6	.7	5.9	4.8	16.9	1.1	1.3

[a] Multiple by 10^{-3}.
[b] A naturally-occurring radionuclide.
ND, less than the sensitivity of analysis.

to maintain clarity and to control water temperature. Newly discharged fuel is placed into an isolated section of the basin that is equipped with a water circulating system. Portable filters and deionizers are provided to remove a large percentage of the radionuclides, and a heat exchanger is used to control basin water temperature. Tritium from the irradiation of the D_2O moderator accounts for the largest quantity of radioactivity released by the reactors to the environment. However, the contribution to the Savannah River results in concentrations less than 1 percent of the AEC standard.

In January 1965, the Beaufort-Jasper Water Authority began operation of a treatment facility to furnish sanitary water, partially supplied from the Savannah River, to most of Beaufort County, S.C. Water is supplied through a canal from the river at a location about 90 miles below the Savannah River Plant. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand. The tritium concentrations in raw water collected from the Beaufort-Jasper Water Plant averaged 2.1 nCi/liter (0.07 percent of the AEC standard) during the July–December period. The annual radiation exposure of an individual in this population due to the consumption of 1.2 liters per day of water containing the very low concentration of tritium is 0.19 mrem, (this exposure may be compared with 20 mrem per year from natural potassium found in the body of all persons or with the 170 mrem per year specified by the Federal Radiation Council as the annual dose guide for members of the public).

Communities near the plant get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed in October. There was no evidence that SRP contributed radioactivity to drinking water supplies; concentrations of alpha radioactivity (1.1 pCi/liter) and beta radioactivity (5 pCi/liter) were essentially the same as those observed before plant startup. Specific analyses

Table 8. Radioactivity in public water supplies, July–December 1970

Sampling points	Alpha radioactivity[a] (pCi/liter)	Nonvolatile beta radioactivity[b] (pCi/liter)
Aiken	0.9	ND
Allendale	ND	ND
Augusta	1.0	8
Barnwell	ND	ND
Bath	1.8	ND
Blackville	.4	ND
Clearwater	ND	ND
Jackson	5.5	10
Langley	2.1	4
New Ellenton	1.0	ND
North Augusta	ND	9
Sardis	ND	ND
Waynesboro	ND	ND
Williston	1.5	ND
Average	1.1	5

[a] AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.
[b] AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.
ND, less than the sensitivity of analysis.

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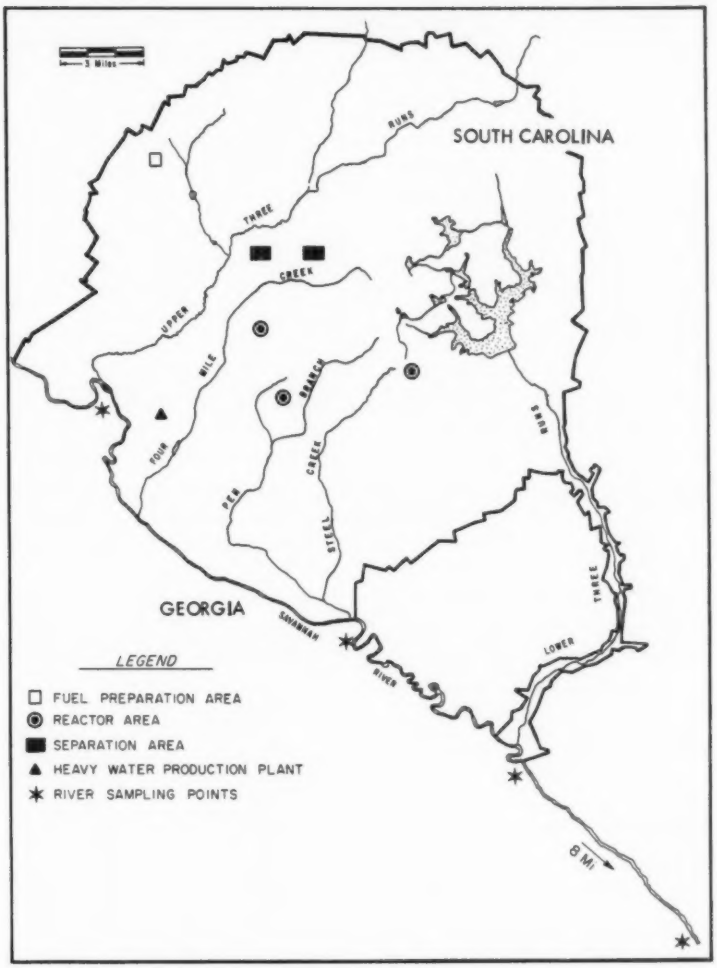

Figure 6. SRP production and effluent streams

showed that the higher than average alpha activity found in some drinking water supplies (for example, 5.5 pCi/liter at Jackson) was due to naturally-occurring radioactivity, primarily thorium-228 and its short-lived daughter products. Radioactivity in public water supplies data is presented in table 8.

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 6. Concentrations of alpha and nonvolatile beta radioactivity in river water for the past year are presented in table 9. Average concentrations of specific radionuclides found in river water during July–December 1970 appear in table 10.

Tritium, sulfur-35, and trace amounts of cesium-137, strontium-89, and strontium-90 were the radionuclides of SRP origin detectable in river water at the downstream location. Strontium-90 and tritium from worldwide fallout were also detected in river water upstream from SRP effluents.

Tritium, a beta-particle emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy water moderator in the reactors. The concentration of tritium in river water averaged 0.20 percent of the AEC standard.

Table 9. Radioactivity in Savannah River water, July–December 1970

Sampling point	Alpha radioactivity[a] (pCi/liter)				Nonvolatile beta radioactivity[b] (pCi/liter)			
	July–December 1970			January–June 1970	July–December 1970			January–June 1970
	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average
1 mile upstream from Upper Three Runs Creek (control)	0.4	ND	ND	ND	8	ND	4	ND
Downstream from Steel Creek	.5	ND	ND	ND	26	ND	7	4
Downstream from Lower Three Runs Creek	.4	ND	ND	ND	16	ND	8	8
8 miles downstream from Lower Three Runs Creek (Highway 301)	.3	ND	ND	ND	15	ND	7	6

[a] AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.
[b] AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.
ND, less than the sensitivity of analysis.

Table 10. Average concentration of radionuclides in Savannah River water July–December 1970

Radionuclides	Concentration (pCi/liter)			
	Sensitivity	Control (1 mile upstream from Upper Three Runs Creek)	Highway 301 (8 miles downstream from Lower Three Runs Creek)	Percent AEC standard at Highway 301
Tritium	600	730	5,850	0.20
Sulfur-35	5.0	ND	4.1	.01
Chromium-51	4.3	ND	ND	<.001
Manganese-54	.4	ND	ND	<.0004
Cobalt-60	1.4	ND	ND	<.005
Zinc-65	1.1	ND	ND	<.001
Strontium-89	.3	ND	1.5	.05
Strontium-90	.01	.6	1.0	.33
Zirconium-niobium-95	.5	ND	ND	<.001
Ruthenium-103-106	3.2	ND	ND	<.03
Iodine-131	.2	ND	ND	<.07
Cesium-134-137	.6	ND	.9	.008
Barium-lanthanum-140	1.6	ND	ND	<.01
Cerium-141-144	2.5	ND	ND	<.02
Neptunium-239	2.2	ND	ND	<.002

ND, nondetectable, less than sensitivity of analysis.

Fish in Savannah River

Fish, predominantly bream, were collected weekly upstream, adjacent to, and downstream from Savannah River Plant effluents. Specific radionuclide analyses of fish are summarized in table 11. The radioactivity in bone and flesh from fish collected adjacent to and downstream from SRP indicates some minor contribution by SRP. Although measurably higher than similar collections at the control station upstream from SRP effluents, the increase is of minor significance when referenced against intake guides defined by the AEC radiation protection standard.

Table 11. Radioactivity in Savannah River fish July–December 1970

Location	Type of sample[a]	Concentration (pCi/g wet weight)			
		Strontium-89,-90		Cesium-137	
		Maximum	Average	Maximum	Average
Above plant boundary (control)	Bone	38	22	<2	<2
	Flesh	2	<1	<1	<1
Adjacent to plant	Bone	39	25	<2	<2
	Flesh	2	<1	3	2
Below plant at Highway 301	Bone	25	18	<2	<2
	Flesh	<1	<1	2	2

[a] Monthly composites of weekly collections for strontium-89, -90 and cesium-137.

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Vegetation

Radioactive contamination of growing plants may result from sorption of radioactive materials from the soil or from foliar deposition.

Grass samples were collected at seven locations along the plant perimeter and at seven other locations along a 25-mile radius route (these are not designated on figure 7). Bermuda grass was selected for analysis because of its importance as a pasture grass for dairy herds and its availability during all seasons of the year. Samples from each quadrant of the plant site and of the surrounding area were composited for monthly analysis. Gamma-emitting radionuclides in grass samples (excluding beryllium-7) were from fallout. Alpha-particle emitters averaged 0.1 pCi/g at the plant perimeter and at the 25-mile radius locations, the same as observed during the last half of 1969; gamma-ray emitters averaged 11.1 and 9.9 pCi/g, respectively, as compared to 12.0 and 15.3 pCi/g for the first half of 1969. Radioactivity in grass samples is presented in table 12.

Table 12. Radioactivity in vegetation, SRP July–December 1970

Radionuclides	Sensitivity of analysis (pCi/g dry weight)	Concentration (pCi/g dry weight)			
		Plant perimeter (7 locations)		25-mile radius (7 locations)	
		Maximum	Average	Maximum	Average
Alpha emitters	0.10	0.5	0.1	0.6	0.1
Cesium-137	.3	2.0	.7	.9	.5
Cerium-141,144	1.0	9.9	4.3	5.3	3.6
Ruthenium-103,106	1.4	ND	ND	ND	ND
Beryllium-7	3.0	10.2	4.8	8.2	4.4
Iodine-131	.2	ND	ND	.9	.2
Barium-lanthanum-140	6.0	ND	ND	ND	ND
Zirconium-niobium-95	.5	1.5	1.3	2.2	1.2

ND, less than sensitivity of analysis.

Milk

Milk was sampled at three dairies within a 25-mile radius of the Savannah River Plant (figure 7). Samples, collected biweekly, were analyzed for tritium and radioiodine. Strontium-90 and cesium-137 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during July–December 1970 are shown in table 13.

Average concentrations of the radionuclides in milk were 12 pCi/liter of strontium-90 and 40 pCi/liter of cesium-137 compared to 11 pCi/liter of strontium-90 and 20 pCi/liter of cesium-137 during the first half of 1970. Iodine-131 was less than the sensitivity of the analysis (5 pCi/liter) throughout this period. These values are consistent with those reported by the U.S. Public Health Service for most sections of the United States. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level (1,012 pCi/liter) was 0.03 percent of the AEC standard for water.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. The July–December 1970 data (table 14) are characteristic of measurements observed at individual stations for the past several years.

Table 13. Radioactivity in milk from local dairies, Savannah River Plant July–December 1970

Distributing points	Tritium[a] (nCi/liter)			Strontium-90[b] (pCi/liter)		Cesium-137[c] (pCi/liter)	
	Maximum	Minimum	Average	September	December	September	December
Aiken	1.0	ND	0.4	9	11	31	33
North Augusta	3.0	0.9	1.7	19	21	59	66
Waynesboro	2.5	.4	1.1	7	8	34	34
Major distributors[d]	1.7	.4	.8	10	10	36	30

[a] Sensitivity of analysis—0.2 nCi/liter, AEC standard—3,000 nCi/liter.
[b] Sensitivity of analysis—1.0 pCi/liter, AEC standard—300 pCi/liter.
[c] Sensitivity of analysis—20 pCi/liter, AEC standard—20 nCi/liter.
[d] Milk produced in local dairies but sold by major distributors.
ND, nondetectable, less than sensitivity of analysis.

Table 14. Environmental gamma radiation, Savannah River Plant, July–December 1970

Sampling points	Gamma radiation (mR/24 h)		
	Maximum	Minimum	Average
Plant perimeter:			
A	0.24	0.16	0.19
B	.17	.13	.15
C	.21	.11	.15
D	.28	.12	.17
E	.16	.11	.14
Average			0.16
25-mile-radius:			
Aiken Airport	0.15	0.13	0.13
Aiken State Park	.16	.11	.13
Allendale	.21	.12	.16
Barnwell	.22	.14	.17
Bush Field	.23	.15	.18
Langley	.19	.13	.16
Sardis	.20	.12	.16
Waynesboro	.27	.10	.17
Williston	.21	.11	.16
Highway 301	.25	.14	.19
Average			0.16

Summary

The quantity of radioactive waste released by the Savannah River Plant to its environs was, for the most part, too small to be distinguished from natural background radiation or was obscured by fallout from offsite sources. Beta radioactivity in air, which had no relationship to plant operations, was about the same as that observed for the same period of 1969 and was 66 percent of the previous 6-month level. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. The average concentration of any radionuclide in river water at Highway 301 did not exceed 0.3 percent of the AEC radiation protection standard.

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(Includes seismic signals presumably from foreign nuclear detonations)

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THE DETERMINATION OF ACCURACY AND PRECISION LIMITS FOR TRITIUM IN WATER. *Forrest E. Knowles, Jr.* and *Edmond J. Baratta. Radiological Health Data and Reports*, Vol. 8, August 1971, pp. 405–410

This paper describes the procedure for establishing a standard deviation (σ) value for analysis of tritium in water and discusses the results of a technical experiment to test the validity of this value. Since many State, Federal and local laboratories are analyzing this radionuclide on a routine basis a procedure of quality control to assist in producing comparable and accurate data is necessary. As more nuclear power reactors and nuclear fuel reprocessing plants become operative, tritium will be introduced into the environment in greater quantities. Therefore, other agencies are preparing for tritium analysis capability and will be depending upon this quality control program to assess equipment and sample preparation capabilities.

A standard deviation of 10 percent for single determinations for values equal or to greater than 5 nanocuries per liter was established by assessing data from a tritium cross-check program conducted by the Analytical Quality Control Service of the Office of Radiation Programs, Environmental Protection Agency (EPA). The technical experiment results confirmed this value.

KEYWORDS: Accuracy, precision, tritium, water.

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